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COMPETITION, INNOVATIONS AND PRODUCTIVITY: A CRITICAL REVIEW OF RECENT LITERATURE AND SYNTHESIS

Malick Souare, Industry Canada

Working Paper 2008-05

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Abstract

According to conventional wisdom, greater competition enhances productivity directly, and indirectly through its effects on innovation and investments in technology adoption (i.e. fundamental and applied innovation, respectively). To ascertain this widespread view, this paper reviews some (recent and/or influential) theoretical literature and empirical evidence on the impacts of competition on innovations (fundamental and applied) and productivity. In addition, it neatly compares the advantages and disadvantages of the most widely used measures of competition in empirical studies. Although there is no obvious and accurate way to measure competition, the price-cost margin (or mark-up) and indicators of regulatory reforms seem preferable (despite some shortcomings) for cross-country and cross-industry studies. In addition, the literature review reveals that the effects of competition, particularly on innovations, are quite controversial at a theoretical level. However, apart from a handful of studies, the empirical literature on the whole (both cross-country and country-specific studies) points to a positive effect of competition on innovations and productivity.

Key words: competition, measures of competition, innovation (fundamental and applied), productivity

Résumé

On pense généralement que la concurrence augmente la productivité directement et indirectement par ses effets sur l'innovation et sur l'investissement dans l'adoption de nouvelles technologies, qui équivalent respectivement à la recherche pure et à la recherche appliquée. Pour confirmer cette théorie répandue, le document examine certains des plus récents ou des plus influents ouvrages théoriques et données empiriques sur l'impact de la concurrence sur la recherche (pure ou appliquée) et la productivité. De plus, il compare avec soin les avantages et les désavantages des mesures de la compétition les plus utilisées dans les études empiriques. Bien qu'il n'y ait pas de façon simple et fiable de mesurer la concurrence, la marge bénéficiaire brute (ou marge commerciale) et les indicateurs de réformes réglementaires semblent être à privilégier (malgré certaines lacunes) pour les études internationales ou intersectorielles. L'examen de la littérature révèle que les effets de la concurrence, particulièrement en ce qui a trait à la recherche, sont très controversés sur le plan théorique. Cependant, exception faite d'une poignée d'études, l'ensemble des données empiriques (qu'elles soient transnationales ou propres à un pays) montrent un effet positif de la concurrence sur la recherche et la productivité.

Mots clés : concurrence, mesures de concurrence, innovation (fondamentale and appliquée), productivité

1 Introduction

It is widely acknowledged that productivity is the single most important determinant of a nation's living standard or its level of real income over long periods of time. As a result, Canadian policy makers, as well as the general public, are particularly concerned about Canada's lagging productivity level and/or growth relative to several Organisation for Economic Co-operation and Development (OECD) countries, and in particular to the United States (U.S.). Among the factors that have been put forward to explain Canada's weak productivity performance with respect to the U.S., there are: lower investment in fundamental innovation (as measured, e.g., by R&D intensity), lower investment in applied innovation or the adoption and diffusion of new technologies (as measured, e.g., by ICT investment share), and the lack of competitive pressures (e.g., in product markets).[1] Souare (2007b) provides some statistical evidence on the extent to which Canada trails behind the U.S. in the aforementioned factors.

Furthermore, greater competition is typically seen as a major driving force behind innovation and investment in technology adoption. For example, according to Schmidt (1997) and Aghion and Howitt (1998), the opening up of markets and increased competitive pressures – by raising the threat of losing market share *vis-à-vis* the new and more advanced competitors – motivate existing firms (incumbents) to innovate, adopt new technologies and upgrade their machinery. Also, in its nineteenth report (in 1999), entitled *Research Funding: Strengthening the Sources of Innovation*, the Canadian House of Commons Standing Committee on Industry stressed that competition is probably the single leading catalyst in all types of innovation and, unless it is present, R&D incentives will be of little consequence.

Consequently, the lack of competitive pressure may be one of the *root* factors behind Canada's weak productivity performance. Against this background, this paper aims to review some (recent and/or influential) theoretical literature and empirical evidence on the impacts of competition on innovations (fundamental and applied) and productivity.[2] In addition, it neatly compares the advantages and disadvantages of the most widely used indicators of competition in empirical studies. The literature review reveals that the effects of competition, particularly on innovations, are quite controversial at a theoretical level. However, apart from a handful of studies, the empirical literature on the whole (both cross-country and country-specific studies) points to a positive effect of competition on innovations and productivity.

The rest of the paper is structured as follows. In the next section, we review the theoretical literature on the relationships between product market competition and innovations or productivity. Section 3 discusses the pros and cons of the most widely used

[1] In the literature, the adoption and diffusion of new technologies is referred to as applied innovation and the technology invention or 'true' innovation (as measured, e.g., by R&D expenditures) is referred to as fundamental innovation. Thus, unless otherwise indicated, the world 'innovations', hereafter, means and refers to both types of innovation activities.

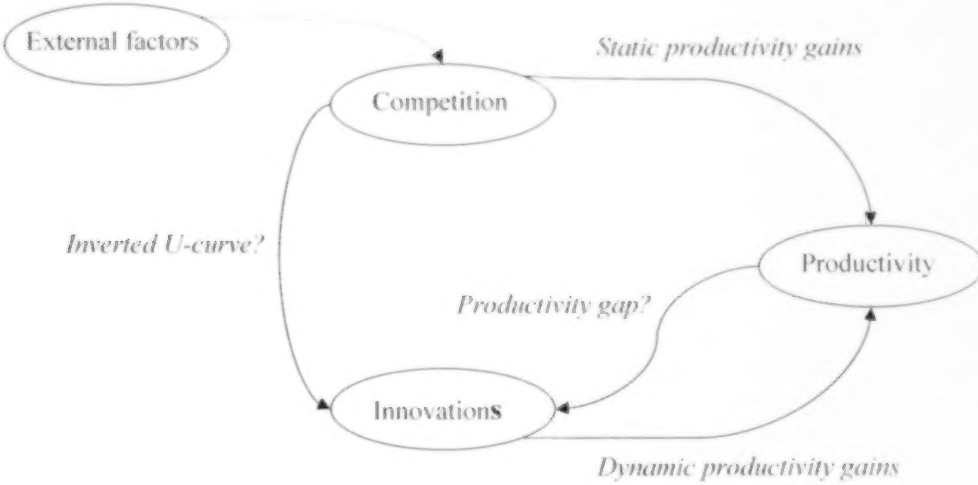
[2] A companion paper, namely Souare (2007b), analyzes empirically the relative importance of competition intensity differential in explaining the Canada-U.S. productivity level gap over the last two decades.

measures of competition and innovations. Then, in section 4, we review the empirical evidence (both cross-country and country-specific studies) on the links between competition and innovations/productivity. Finally, section 5 concludes the paper.

2 Theoretical Literature Review

Figure 1 presents a theoretical framework for links between competition, innovations and productivity. First of all, as we are interested in the *causal* impact of competition on innovations and productivity, it is assumed that external factors (such as policy changes that make entry into a market easier or less costly) lead to exogenous variation in the degree of competition. In assuming so, we can ignore the reverse causality from innovations or productivity to competition.[3]

Figure 1: Relationships between competition, innovations and productivity



As shown in Figure 1, increased competition may affect productivity in both direct and indirect ways, the latter channel through innovations (fundamental and applied). Competition induced productivity improvements from these direct and indirect channels are

[3] Otherwise, while product market competition is likely to affect innovations, it is also the case that successful innovators affect market structure. Firms that are successful innovators will either have lower costs, and so will be able to sell at a lower price, or will have superior quality goods, and in either case will gain market share, thereby reducing competition. The same reasoning holds for high-productivity firms, as productivity is inversely related to marginal costs. Actually, addressing the endogeneity of competition measures has been one of the main challenges in trying to identify the (causal) impact of competition on innovations and/or productivity.

referred to as static and dynamic productivity gains, respectively.[4] In the following, we discuss the main theories or intuitions underlying each mechanism (or channel) and the reverse impact of productivity (gap) on innovations, which has been one of the key predictions of recent endogenous growth literature.[5]

Direct impact of competition on productivity

Greater competition can improve productivity directly by leading to better resource allocation and by reducing organizational slack in the use of inputs, particularly managerial slack under asymmetric information or moral hazard situations.[6]

Firms operating under imperfect competition (e.g. firms with a monopoly or oligopoly power) may create output shortage in certain activities to generate scarcity rents, thereby forcing resources to move to other activities where they are not employed as productively. Similarly, an inefficient firm or industry uses more resources and factor inputs than required by a particular technology, therefore tying resources to low-productivity activities and reducing the overall allocative efficiency of an economy. Exposure to a greater level of competition forces inefficient firms to restructure, freeing resources for other productive uses. According to OECD (1995), this process of resource (re-)allocation, which includes the entry and exit of firms, provides an important contribution to the structural change of OECD economies.

Besides, it may be difficult for owners of monopolistic firms to enforce 'maximum efforts' even if they intend to, since in markets with little competition there is a lack of other firms to serve as a standard of reference and the threat of company failure may be limited. A similar situation arises when firms operate under asymmetric information or moral hazard circumstances, in which cases the owner of a given firm is unable to attribute firm's poor performance to either insufficient managerial efforts or bad economic situations. Thus, there is a variety of agency or principal-agent models (see, e.g., Holmstrom, 1982; Hart, 1983; Lazear and Rosen, 1981; Nalebuff and Stiglitz, 1983; and Aghion and Howitt, 1998) which indicate that monopoly rents are often captured by managers (and workers) in the form of managerial slack or reduced work effort, and that product market competition would discipline firms into efficient operation. Overall, these models have identified at least three different theoretical channels. First, competition creates greater opportunities for comparing performance, making it easier for the owners or the market to monitor managers and, thereby induce higher effort and greater efficiency from their managers. Second, since more competition is likely to raise the likelihood of

[4] The distinction between static and dynamic gains is employed mainly for the ease of presentation. In general, factors that imply one-time change in the level or growth of productivity (or output) are by definition static; but when transition processes involve changes in growth rates over longer periods, they are referred to as dynamic. Therefore, the distinction is not independent of the time horizon of the analysis.

[5] It is worth mentioning at this stage that since the role of innovation and diffusion of new technologies as engines of productivity improvements is both theoretically and empirically well established, we here escape discussing their impacts on productivity. Thus, we assume that the sign of the competition effect on productivity is determined by that of its impacts on innovations.

[6] Inefficiency or slack in the use of input is often referred to as 'X-inefficiency'.

bankruptcy at any given level of managerial effort, managers may work harder to avoid this outcome. Third, cost-reducing improvements in productivity could generate higher revenue and profit in a more competitive environment where price elasticity of demand tends to be higher. Also, as well as managerial effort, if product market rents are partly shared with workers in the form of higher wages or reduced effort, then competition probably influences workers' behaviour too.

Nonetheless, there is a handful of theoretical agency models (such as Martin, 1993 and Scharfstein, 1988) that indicate that greater competition (under some assumptions) leads to an increase in managerial incentives to slack. The key argument is that marginal revenue declines as product market competition increases, so the owner has less incentive to pay the manager to reduce costs, consequently the latter's marginal utility from income reduces, which pushes him/her to shirk.

Indirect impact of competition on productivity

While there is little disagreement on the static productivity gains from stronger competition, the effect of increased competition on innovations (a channel through which it may indirectly lead to dynamic productivity gains) is less clear-cut, and has been quite controversial in the literature. The main theories involved are briefly discussed below.

Schumpeter (1934) is credited with initiating the idea that monopolistic or large firms have both the financial resources and the incentives to undertake investment in innovation. He emphasized the costly, risky and uncertain nature of innovation activities and the crucial issue of the 'appropriability' of the economic benefits of innovation. Given these, he argued that large firms (with deeper pockets) and ex-ante monopolistic power might be more conducive to innovation than fully competitive markets populated by small firms. In other words, the Schumpeterian argument is that uncertainty and competition reduce the expected pay-off from an investment in R&D and therefore contract firm R&D.

In contrast, Arrow (1962) put forward a model where, under certain assumptions, there is a higher incentive to innovate for a perfectly competitive market than a monopoly. A key assumption for Arrow's result is that there are 'perfect' intellectual property (IP) rights, in the sense that the innovator can license the innovation at full market value.

Porter (1990) also advocates competition and insists that (local) competition has a positive impact on productivity and growth. In his view, competition accelerates imitation and improvement of innovations. Although competition reduces the returns to the innovator (due to larger spillovers flowing to competitors), the amount of innovative activity will increase, because firms are "forced" to innovate: firms that fail to improve products and production processes in due time will lose ground to their competitors and will ultimately go bankrupt. Porter gives striking examples of Italian ceramics and gold jewelry industries and the German printmaking industry that grew through rampant imitation of new technologies and improvement on them. He argues that hundreds of firms in these industries are located together and fiercely compete to innovate since alternative to innovation is demise.

The prediction that competition has an unambiguously negative effect on innovations, which is often called in the literature 'the Schumpeterian effect', is shared by both the early models of endogenous growth theory (e.g. Romer, 1990; Aghion and Howitt, 1992; Grossman and Helpman, 1991) and typical IO models (e.g. Dasgupta and Stiglitz, 1980; Dixit and Stiglitz, 1977). In all of these models, an increase in product market competition has a negative effect on innovations, thereby on productivity, because it reduces (more quickly) the monopoly or post-entry rents that reward new innovations – and this eventuality is what discourages firms from engaging in innovations activities. An increase in the ability of other firms in the industry to imitate has a similar effect.[7] Typically, in the early models of endogenous growth theory, all innovations are made by outsiders (new entrants) à la 'creative destruction' manner and innovations incentives depend crucially on post-innovation rents.

Since most early empirical studies on the link between competition and (fundamental) innovation failed to lend support to the Schumpeterian hypothesis,[8] the recent endogenous growth theories extended their models to allow competition to exert some positive impact on innovation, and some theories even allow for positive and negative effects (for different parameter values) within the same model.

Thus, Aghion *et al.* (2005)[9] and Aghion *et al.* (2004a, 2004b) have made some interesting theoretical contributions, which have received recent empirical interest. In fact, without any exaggeration, we could say that these contributions have become the 'state of the art' of recent empirical studies looking into the link between competition and (fundamental) innovation – particularly those using firm or industry-level data within a single economy.

Aghion *et al.* (2005) develop a theoretical model (eventually tested empirically) in which both current technological leaders and their followers (in any industry) can innovate, and innovations by leaders and followers all occur step-by-step. Moreover, innovation incentives depend on the *difference* between *post-innovation* and *pre-innovation* rents of incumbent firms (the latter rents were equal to zero in previous models where all innovations were made by outsiders in a radical fashion). They argue that in this case, more product market competition may end up fostering innovation (and productivity), as it may reduce a firm's pre-innovation rents by more than it reduces its post-innovation rents. In other words, competition may increase the incremental profits from innovating, and thereby encourage R&D investments aimed at 'escaping competition'.[10] Their model leads to the following three results:

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[7] It is worth mentioning that although we use the word 'innovations', these studies more focus on fundamental innovation; but since the same arguments are relevant to applied innovation, we refer to both of them.

[8] Cohen and Levin (1989) provide a comprehensive survey of this early empirical literature. See also the review by Kamien and Schwartz (1982).

[9] Note that an earlier version of this paper was published in 2002 as NBER Working Paper 9269.

[10] They stress that this should be particularly true in industries where incumbent firms are operating at similar technological levels, which they refer to as 'neck-and-neck' industries. In this case, pre-innovation rents should be especially reduced by competition. On the other hand, in

- First, as shown in Figure 1, they generate an inverted-U relationship (i.e. a hump-shaped relation) between competition and innovation, which indicates that neither monopoly nor fully competitive market structures are the most conducive to innovations – an intermediate market structure generates the highest rate of innovation activities.

- Second, they illustrate that the average technological distance between leaders and followers (i.e. the productivity gap) increases with competition.

- Finally, they report that the inverted-U is steeper for neck-and-neck industries, i.e. the (positive) competition effect on innovations is amplified when firms compete neck-and-neck. This is because the gain due to an innovation, which results in taking technological lead, is high. Recall, e.g., that monopoly profits are greater than the sum of duopoly profits.

Aghion *et al*. (2004a, 2004b) introduce firm entry into a model similar to Aghion *et al*. (2005) and allow incumbent firms to innovate. In their model, three mechanisms link entry (which can reflect competition in a market) and productivity performance: the 'batting average' effect, in which technologically more advanced entrants have higher productivity growth, leading to a reallocation of inputs from lower productivity firms; the imitation effect, where incumbent firms improve organization and reduce slack, imitating new entrants' practice; and finally the 'innovate to escape' effect, where incumbents raise innovative effort in response to the threat of entry, in order to escape having to compete. In all three cases, entry, or the threat of it, is predicted to raise productivity. In fact, their model involves the following two main theoretical predictions:

- First, the threat of new entrants has a positive effect on TFP growth in domestic incumbent firms. Productivity growth by incumbents is affected (mainly) by entry threat through its effect on innovation incentives.

- Second, they show that the affect of increasing entry threat depends on the country, industry or firm's distance to the frontier. More specifically, in countries or industries that are close to the (world) technological frontier, fostering entry or competition will increase incumbents' incentives to innovate in order to escape potential entrants or competitors. However, in countries and industries that lag far behind the frontier, higher entry or higher competition on their own tend to discourage incumbent firms from innovating – these firms have no hope to win against a potential entrant, and therefore the only effect of an increased entry threat is to reduce the firms' expected pay-off from investing in R&D.

Besides, in the Aghion *et al*. (2004a, 2004b) model, if there is no threat of entry then incumbent performance would be greater the further the sector is from the frontier (i.e. the level effect of the distance to the frontier would be positive). As we will see

industries where innovations are made by follower (or laggard) firms with already low initial profits, competition will mainly affect post-innovation rents, and therefore the Schumpeterian effect of competition should dominate.

subsequently, such a positive effect of the initial distance to frontier on productivity growth is in fact found in many (empirical) models with convergence.

Thus, one of the key theoretical predictions of both Aghion *et al.* (2004a, 2004b) and Aghion *et al.* (2005) is that the innovative behavior of firms (industries or countries) varies with their distance to the technological frontier. This distance is often measured (at the industry level) as the difference in TFP between each country-industry and the technological leader (the corresponding country-industry with the highest level of TFP). This potential impact of productivity gap on (followers') innovations is depicted as well in Figure 1.[11]

Summing up, the effects of competition on innovations and productivity are, at a theoretical level, ambiguous. In the end, the answer has to be found empirically. However, before reviewing the empirical evidence on these relationships, it is relevant to discuss briefly the pros and cons of the most widely used measures of competition (and innovations) in empirical studies.

3 Measurement Issues

The way to measure competition and innovations is still an unsettled topic in the literature. In this section, we discuss briefly the pros and cons of the most widely used measures for each of them.

3.1 Measuring innovations

In empirical studies, the most commonly used measures of (fundamental) innovation intensity have been R&D spending and patenting activity, with the former and latter being respectively an input and output measure. Thus, at first glance, patent data might be an appropriate measure of innovation. However, according to Gustavsson and Poldahl (2006), the patenting propensity varies enormously across firms and industries. For instance, some firms may both innovate and perform relatively much R&D without that showing up in the patent statistics. Therefore, patent data might be more appropriate in an analysis on a limited number of industries.

The advantage of using R&D intensity data is that they are available for many countries and industries on a comparative basis. Nevertheless, it must be borne in mind that the use of R&D intensity as an indicator of innovation suffers from important limitations (Bassanini and Ernst, 2002). As mentioned above, R&D intensity is an indicator of input in the innovative process rather than output. Consequently improvements in the efficiency of the innovation process (greater output with less input) can be mistakenly interpreted as a

[11] A further rationale behind the reverse causality (from productivity to innovations) is that better performing firms (or industries) – those with higher productivity levels or growth – are more likely to innovate and to devote more of their resources to innovations. Cainelli *et al.* (2006), for example, provide strong empirical evidence on the two-way relationship between innovations and productivity. This mutual endogeneity is also considered in Souare (2007b).

reduction of the innovative effort. Moreover, R&D intensity conveys only information about formal innovation expenditure. In many industries informal innovation is a sizeable component of overall innovation activity. Also, reported data tend to overestimate R&D intensity of large firms relative to small firms. Small firms typically undertake much informal R&D and are not included in the R&D statistics if they do not have at least one full-time research employee.

Regarding the applied innovation, it is harder to measure the extent of the adoption and diffusion of new technologies. Some empirical studies rather consider a country or industry's scope for benefiting from technological diffusion, which they proxy by the distance that it lies behind the technological frontier, and this distance is often measured (at the industry level) as the difference in TFP between each country-industry and the technological leader (the corresponding country-industry with the highest level of TFP). However, this measure is typically used as an explanatory variable in models of productivity convergence (or catch-up) across countries or industries. Besides, a handful of studies, addressing the *causal* impact of competition on the adoption and diffusion of new technologies, have proxied the latter by using domestic (broad) capital investment (see, e.g., Alesina *et al.*, 2005) or more specifically investment in ICT (see, e.g., Conway *et al.*, 2006). Actually, ICT investment has been highlighted as one of the major channels through which technology spillovers or diffusion occurs.

3.2 Measuring competition

There is no obvious and accurate way to measure competition. Nonetheless, the following indicators have been widely used in empirical studies: market share, Herfindahl index, price-cost margin (or mark-up) and its refined versions,[12] import penetration, firm entry into a market, and indicators of regulatory reforms aimed at improving competition. Next, we discuss them in turn.

- **Market share and Herfindahl index**

Market share and Herfindahl index (which measures the concentration of market shares)[13] are often used in competition studies. More competitors and/or more equally distributed market shares result in a lower value of the Herfindahl index, indicating increased competition. One problem with these measures is that they depend crucially on precise definitions of geographic and product markets (i.e. the relevant market where competition occurs) and tend to neglect potential as well as international competition. Thus, in highly integrated international markets, the Herfindahl index (which focuses on domestic markets) is more appropriate for large economies (where the domestic market is the main market) than it is for small economies and small markets.[14] Consequently, for a small open

[12] Those versions include profit persistence measure and profit relatives measure.

[13] The Herfindahl index is defined as the sum of the squares of the market shares (in terms of output or employment) of all firms or the largest *n* firms in a market. The Herfindahl index has values between 0 and 1, from perfect competition to monopoly.

[14] For example, the US competition authorities use the Herfindahl index as a guideline for making decisions on approving mergers and acquisitions.

economy such as Canada, the use of Herfindahl index – as an indicator of the degree of competition faced by firms (or industries) – may be extremely misleading as many Canadian firms, particularly those in manufacturing, operate in international markets.

- **Price-cost margin or mark-up**

Measures of profitability (rents) are widely used as indicators of competition intensity in many studies. The price-cost margin (further abbreviated as PCM), also known as 'Lerner index', refers directly to the firm's ability to set its prices above its marginal costs – In other words, the PCM measures the mark-up that firms charge. A low degree of product market competition results in high mark-ups. Thus, if firms are unable to segment markets, the PCM might be preferable to the Herfindahl index. This is because the PCM might be a function of not only the degree of competition in the domestic market but also of competition on foreign markets. Further, it might also reflect the threat of potential entrants – In fact, the PCM accounts for all aspects of competition. However, one weakness of this measure is that it uses the marginal costs, but these costs are not directly observable. In the empirical literature, however, it has been standard to approximate the firms' marginal costs by the average variable costs – although this may create a bias in the computation of this indicator.[15] Another drawback is that in addition to product market competition, other factors (such as demand fluctuation, cost shocks, technological opportunity, R&D appropriation, etc) may affect the measure of the mark-up – this in turn involves serious endogeneity issues on the relationships between PCM and innovations or productivity.

However, despite these shortcomings, Boone (2000) argues that the mark-up measure of competition is more robust than many commonly used measures, particularly those based on market concentration and market shares. In addition, the mark-up is the only commonly used measure of competition that is available across countries and industries without using firm-level data. Further, since these measures (such as the Lerner index) are often non-monotonic in competition, some authors have refined the PCM by using it to compute related indicators, such as relative profits measure (see, e.g., Boone, 2000; Creusen *et al.*, 2006) and profit persistence measure (see, e.g., Greenhalgh and Rogers, 2006). Although these measures will not be discussed at length here – as they have been scarcely used in empirical studies – it is worth having their general meaning. The profit persistence literature is based on the assumption that all firms will experience profit shocks and that the degree of competition from other firms determines how long this shock will persist. Thus, the average degree of profit persistence in an industry is obtained by estimating an autoregressive process of order one (AR(1)) with the PCM of a group of firms within that industry – obviously, the coefficient on AR(1) represents the persistence to a profit shock, and a high value (of that coefficient) implies less competition. On the other hand, the relative profits measure (RPM) is based on the idea that fierce competition provides efficient firms with relatively more profits than inefficient firms. With greater competition, efficient firms can reduce their prices (given their lower marginal costs) relatively more than inefficient firms and sell more products, thereby make more profits. Therefore, assuming that firms have different efficiency levels or marginal costs – as

[15] From the basic microeconomic theory, we know that the marginal cost is equal to the average variable cost only when the latter cost is at its minimum.

productivity is inversely related to marginal costs – the RPM is approximated by regressing a firm's profits on its marginal costs, where the estimated slope represents the RPM. A high value of that coefficient corresponds with a high level of competition.

- **Import penetration**

Import penetration rate – the ratio of imports to production – is often used as the contribution of foreign firms to competition in a domestic market. As mentioned earlier, the PCM may be influenced not only by domestic producers but also by the degree of competition from foreign producers and competition on foreign markets, whereas the Herfindahl index only takes the number of domestic producers and the distribution of market shares among these into account. Thus, when using the Herfindahl index, many empirical studies typically use import penetration ratio to control for the impact of foreign competition in domestic markets. However, some authors argue that import penetration may proxy international technological spillovers rather than the level of competitive pressure (e.g. Coe and Helpman, 1995; Frantzen, 2000).

- **Firm entry**

The number of firms entering a market might be a measure of market competition. But it is generally believed that firm entry suffers a heavier potential endogeneity problem as entrants may typically have information about future growth developments and may decide upon entry accordingly.

- **Product market regulations and reforms**

International institutions, such as the OECD, have constructed some cross-country and -industry comparable indicators of product market regulations and reforms aimed at strengthening competition. However, according to Griffith *et al.* (2006a), a main drawback of these economy-wide and sector-specific measures is that they refer in general to the situation in a single year, and therefore do not change over time. This is problematic for two reasons: first it is purely cross-sectional information, and second it implies an underlying assumption that that specific-year values are representative of cross-country patterns of regulatory reforms over the sample period considered. This will not be true if some countries have, e.g., liberalized their markets faster than others – Typically, the timing, extent, nature, and starting point of these reforms vary across countries and industries. Griffith *et al.* (2006a) strongly argue that these problems make causal interpretations of the results extremely problematic. More specifically, the purely cross-sectional measures of regulation do not allow identifying separately the impact of regulation from other unobservable factors that affect competition and innovations outcomes across countries/industries. But, with time-varying measures of regulation, one can use panel data techniques that control for any unobservable factors that do not change over time.[16]

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[16] The OECD also computed some time-varying indicators of regulation, but these refer to specific aspects of regulation in seven non-manufacturing industries. In contrast to what is often assumed in certain studies, Griffith *et al.* (2006a) think that these indicators are unlikely to be

However, to an OECD study (Bassanini and Ernst, 2002), a further advantage of relying on (weighted) indicators of regulation rather than more direct measures of competition is to mitigate endogeneity problems as well as issues related to the fact that usual measures (such as the Lerner index) are often non-monotonic in competition. But, Griffith *et al.* (2006a) also argue that aggregating the information on product market regulations into a single summary measure imposes strong and possibly arbitrary restrictions on the way in which individual regulations can affect innovations and/or productivity.

Finally, it is important to keep in mind the following observations by Gustavsson and Poldahl (2006). They argue that variation in the measured level of competition may have a different interpretation in the cross-sectional and time series dimension. In the cross-section, a high PCM (or Herfindahl index) might be the outcome of scale effects or lack of competition, or a combination of both. In the time series dimension, one can ignore scale effects and fixed factors that affect firm R&D. A new entrant in an industry, implying a decreasing scale of the Herfindahl index, will only be related to the measured level of competition in the same industry at a specific point in time. Therefore, in the time series dimension, the dynamics of competition variables have a clear interpretation. However, this comes at a price. First, we lose potentially valuable cross-sectional information. Secondly, even if individual firms' market shares vary over time and competition is fierce, industry-based measures of competition might be rather stable. This leads to low time series variation in data, large standard errors and potentially an under-evaluation of competition.

Thus, bearing in mind these advantages and drawbacks of different (direct) measures of competition or measures of regulations and reforms aimed at strengthening competition, we review in the next section the empirical evidence on the relationships between competition and innovations (or productivity).

4 Empirical Literature Review

In this section, we consider two key strands in the empirical literature, cross-country and country-specific studies. Since the companion empirical paper (i.e. Souare, 2007b) is concerned with cross-country case, we will further scrutinize the approaches undertaken in some of those studies.[17]

4.1 Cross-country studies

Using a two-country general-equilibrium (simulation) model, Bayoumi *et al.* (2004) examines the macroeconomic benefits and international spillovers of an increase in

representative of regulatory trends in the economy as a whole. They consider the nature of regulation in those industries to be qualitatively different from regulation in the rest of the economy, both in terms of its goals and its effects.

[17] Recall that Souare (2007b) investigates empirically the role of competition intensity differential in the Canada-U.S. productivity gap.

competition, as measured by decreasing markups. After calibrating the model to the euro area vs. the rest of the industrial world, the paper leads to three conclusions. First, greater competition produces large effects on macroeconomic performance, as measured by standard indicators. In particular, they show that differences in competition can account for over half of the current gap in GDP per capita between the euro area and the US.[18] Second, it may improve macroeconomic management by increasing the responsiveness of wages and prices to market conditions. Third, greater competition can generate positive spillovers to the rest of the world through its impact on the terms of trade.

There is a small but growing literature investigating the impact of product market regulations and reforms – aimed at strengthening competition – using (panel) data across countries and/or industries. A World Bank study by Dutz and Hayri (2000) uses cross-sectional data from over 100 countries to explore the relationship between the intensity of economy-wide competition and economic growth. Since they have fewer observations on competition variables than on the more standard growth variables and intend to use all available information as efficiently as possible, they proceed basically in two steps.[19] First, they estimate a cross-country growth model using, among others, human capital, investment in physical capital, and openness as explanatory variables.[20] In the second step, they calculate the (raw) correlations between the competition variables and unexplained growth – the latter being the residuals from the estimation done in the first step. Their results indicate that there is a strong positive and robust correlation between long-run growth and effective enforcement of antitrust and competition policy. However, it is needless to say that these results are an evidence for a positive association between competition and economic growth rather than a causal impact of the former on the latter.[21]

Using a cross-section of 18 OECD countries and 18 manufacturing industries, Bassanini and Ernst (2002) estimate a single equation to investigate the impact of product and labour market regulations on innovation (measured by R&D intensity). As indicators of product market regulation they use measures of anti-competitive inward-oriented economic regulation (state control, legal barriers to entry, price controls, etc…), indicators of tariffs and non-tariffs trade barriers, plus economy-wide measures of both administrative regulation (administrative barriers on start-ups, features of the licensing and permit system, etc…) and protection of Intellectual Property Rights (IPRs).[22] Their estimation results indicate that there is an unambiguous negative association between R&D intensity and indicators of non-tariff barriers and inward-oriented economic regulation. Conversely,

[18] More specifically, their simulations indicate that increasing competition in the euro area toward U.S. levels could boost output by 12.4% in the euro area as both investment and hours worked rise markedly, and by 0.8% in the rest of the world. The consumption benefits are more evenly spread – 8.3% and 1.3%, respectively – in part because the euro depreciates (in real terms) against the dollar.

[19] Most of the competition variables are static (i.e. refer to specific year) and the smaller subset of countries that each competition indicator covers also varies.

[20] These variables that vary over time are averaged over 1986-1995.

[21] It is worth noting, however, that given their small number of observations on competition variables, running a regression to assess this causal impact may result in large standard errors, thereby lead to a potential under-evaluation of competition impact.

[22] These indicators are all time-invarying variables and the R&D intensity has been averaged across 1993-1997.

stronger protection of IPRs tends to be positively associated with higher R&D intensity, although the authors emphasize that endogeneity problems do not enable them to identify this association as a causal relationship.

Alesina *et al.* (2005) look at the effects of regulation on (domestic) investment in a panel of services industries. They measure regulation with different time-varying indicators that capture entry barriers and the extent of public ownership, among other things, from 1975 to 1998 in 21 OECD countries for seven non-manufacturing industries: transport (airlines, road freight and railways), communication (telecommunications and postal services) and utilities (electricity and gas). After estimating a simple dynamic panel model of investment and regulation, they find significant positive impact of product market regulatory reforms on investment. A component of reforms that plays a particularly important role is entry liberalization, but privatization also has a positive effect on capital accumulation. They also investigate whether the magnitude, initial level, and timing of regulatory reforms matter. Interestingly, they report evidence that the marginal effect of deregulation on investment is greater when the policy reform is large and when changes occur starting from relatively low levels of regulation. In other words, small changes in a heavy regulated environment are not likely to produce much of an effect. Moreover, they find that deregulation has a statistically significant greater effect for countries-sectors that have undertaken reforms early on in their sample. Thus, these results on the impact of timing, extent, and initial level of regulatory reforms show that non-time-varying measures may be inappropriate as discussed earlier. Finally, it is worth mentioning that the overall results are robust to changes in estimation approaches (including dynamic fixed effects and GMM techniques) and to a number of other extensions (e.g., controlling for additional variables, such as factor prices, various business cycle measures, and so forth).

A series of three OECD studies (Scarpetta and Tressel, 2002; Nicoletti and Scarpetta, 2003; Conway *et al.*, 2006) use basically the same empirical model of productivity convergence (or catch up) across countries and industries to investigate the effect of product market regulations on labour and total-factor productivity growth. In this empirical framework, innovation and technology transfer provide two potential sources of productivity growth for a country/industry behind the technological frontier (the productivity leader). They examine the roles played by product market regulations – aimed at strengthening competition – in stimulating each source of productivity growth.[23]

Scarpetta and Tressel (2002) analyse the impact of innovation activity (proxied by R&D intensity) and product and labour market institutions on TFP growth in a panel of 23 two-digit industries (17 manufacturing and 6 business services) in 18 OECD countries over

[23] In fact, this model is (roughly) the model developed by Griffith *et al.* (2004, 2000) to assess the relative importance of innovative and learning effects of R&D (and trade, human capital) in explaining the productivity growth in a panel of OECD industries. It has also been used by Cameron *et al.* (2005) to address these same issues in an UK-specific study, where the US within-industries were the technological frontier. *Intuitively*, the three OECD studies we are about to discuss adapt the model from Griffith *et al.* (2004, 2000) by substituting the extent of product market regulations for R&D, arguing that competition may induce firms to innovate and for firms behind the frontier to adopt best practice and up-to-date technologies – thereby increasing the speed with which those firms/industries catch up to the productivity leader.

the period 1984-1998. They find, among other things, that anti-competitive product market regulations are negatively associated with productivity performance. Moreover, the negative effect is larger the further a country/industry is from the technological frontier, because such regulations hinder the process of technology adoption – For example, if the adoption of new technologies relies partly on new firms, high entry barriers may reduce the pace of adoption.

Nicoletti and Scarpetta (2003) use the same data as in Scarpetta and Tressel (2002), but focus only on the links between regulations in product market and growth in TFP. They find that various measures of anti-competitive product market regulation (both economy-wide and industry-specific) significantly curb productivity performance at the industry level. Again, they also report that the negative impacts, in terms of foregone productivity improvements, are higher in countries that are further away from the technological frontier. Using their empirical results to illustrate the potential productivity gains that would be induced by regulatory reforms, their simulations indicate that a product market reform that would align industry-specific regulations with those of the most liberal OECD country is estimated to reduce the TFP gap *vis-à-vis* the leading country by around 10%, in the long run, in high-gap countries such as Greece, and by around 4 to 6 percentage points in several other continental European countries and Japan. Put differently, aligning the overall regulatory stance with that of the most liberal OECD country could increase the annual rate of TFP growth in continental EU countries by between 0.4% and 1.1% over a period of ten years.

Conway *et al.* (2006) use labour productivity growth as measure of productivity performance – instead of TFP growth as in the previous two studies – but estimate basically the same model at both the aggregate business sector and sectoral levels. The countries and sectors they cover are also slightly different, as well as the sample period. The aggregate business sector model is estimated over the period 1978 to 2003 for the subset of 21 OECD countries for which the aggregate indicator of regulation in seven non-manufacturing sectors exists. The sectoral version of the model is estimated for 20 sectors over the period 1981 to 2003 for the same countries except one. In the sectoral model estimation, regulation is proxied by the "regulation impact" indicators, which cover both manufacturing and non-manufacturing industries over the sample period.[24] Overall, their empirical results indicate that restrictive product market regulations hinder the rate (or speed) of technology adoption/diffusion from the leader country. Regarding the differential impact of each country/industry's distance relative to the productivity leader, similar results to the previous two studies are reported. Moreover, they also investigate two channels through which product market regulations might affect the international diffusion of leading technologies, namely the adoption of ICT and the location decisions of multi-national enterprises, measured respectively by the ICT investment share and employment share of foreign

[24] The indicators of regulation impact are sectoral indicators that measure the 'knock-on' effects of regulation in non-manufacturing sectors on all sectors of the economy. These indicators are predicated on the notion that anti-competitive regulations in non-manufacturing sectors not only have a direct influence on market conditions in these sectors, but also have a less visible impact on the cost structures faced by firms that use the output of non-manufacturing sectors as intermediate inputs in the production process. For further details on the construction of these impact indicators, see their paper.

affiliates. In both cases the effect of anti-competitive product market regulation is found to be negative and significant.

One key limitation, however, of the analysis in Nicoletti and Scarpetta (2003) and Scarpetta and Tressel (2002) is that they only have time-varying measures of product market reforms for a small number of non-manufacturing industries. For the rest of the economy they use a single cross-section of regulation indicators for 1998, which is the last year of their sample period. Similarly, in their aggregate business sector model, Conway *et al.* (2006) proxied regulation by the aggregate indicator of regulation in seven non-manufacturing sectors, which they assumed to be representative of regulatory trends in the business sector as a whole – recall about the Griffith *et al.* (2006a) comments on these assumptions.

Another shortcoming of these studies is that they all consider only one type of technology diffusion and catch-up processes, which is known as the confined exponential diffusion process, and has received most attention in the existing empirical literature.[25] One unappealing feature of this technology diffusion process is that it implies the further a country (or an industry) is away from the technological frontier, the greater the potential for technology spillovers, and therefore the higher its rate of productivity growth. This feature translates into the results reported by the three OECD studies, in that they all find the negative productivity impact of anti-competitive product market regulations to be larger the further a country (or an industry) is from the technological frontier.[26] In other words, pro-competitive regulations (or increases in competition intensity) have higher positive impacts on productivity the further a country/industry lags behind the frontier. But recall, this is exactly the opposite of what is predicted by recent endogenous growth literature.

Similarly, using the same framework (as in the three OECD studies), Griffith *et al.* (2004) find the overall social rate of return to R&D (i.e. from both R&D-based innovation and absorptive capacity) to be higher in the follower countries (such as Canada) than in the frontier (the U.S.). This finding has raised the important question of why many non-technological frontier countries (such as Canada) do not invest more in R&D – relative to the U.S. – since its overall return is higher?[27].

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[25] The functional form for this diffusion process, which was first specified by Nelson and Phelps (1966), is as follows: $\Delta \ln A_i = g(X_i) + c(X_i)\left[\left(A_m / A_i\right) - 1\right]$, where A is, e.g., the TFP, the indices i and m stand for the follower and leader country, respectively. X is a vector that may include R&D, Trade, Human capital and a constant. As done in the three OECD papers, one may substitute competition indicator for R&D.

[26] This deserves attention, especially as our scrutinizing of the results in the three papers indicates that the source of productivity growth that is always conclusive is the (indirect) effect of regulation through the speed of the catch up (i.e. the interaction of regulation and productivity gap). The direct effect is often insignificant or, even significant, it becomes either insignificant or enters with the wrong sign when the interaction term is introduced in the estimation.

[27] Overall, these results follow from the fact that the marginal product of R&D (or inverse competition indicator) depends on the technological level gap. More formally, with $\Delta \ln A_i = g(X_i) + c(X_i)\left[\left(A_m / A_i\right) - 1\right]$, the marginal product of X (MPX) is given by

However, there exists an alternative technology diffusion or catch-up process, namely the logistic model of technology diffusion, which may lead to conflicting results. As in the exponential diffusion process, the logistic model stipulates that the further a country (or an industry) is from the technological frontier, the greater the potential for technology spillovers, *but* it also involves the lesser its absorptive capacity or speed of the catch up.[28] According to Benhabib and Spiegel (2003), the implications of exponential versus logistic technology diffusion for economic growth can be quite divergent, with convergence guaranteed in the former case and possible 'convergence clubs' in the latter case.

Thus, using the logistic model of technology diffusion, some key findings in both the three OECD studies and Griffith *et al.* (2004) may be completely reversed. Consequently, an important contribution over the existing empirical literature would be to ascertain this possibility.[29]

Finally, in a very recent paper, Griffith *et al.* (2006a,b), using a panel of 9 countries and 12 two-digit manufacturing industries over the 1987-2000 period, estimate three equations that investigate respectively the impact of regulatory reforms on product market competition (PMC), the effect of PMC on (fundamental) innovation, and the effects of both PMC and innovation on TFP growth. In order to address the possible endogeneity of the competition variable, as measured by average profitability or markup, they use reforms carried out under the EU Single Market Program (SMP) to elicit exogenous variation in the degree of industry-wide competition, hence their first equation.[30] Thereafter, the exogenously 'explained' competition – i.e. the predicted value – is used in the subsequent

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$MPX = g'(X_i) + c'(X_i)\left[\left(A_m/A_i\right) - 1\right]$, where $g'(X)$ and $c'(X)$ denote the first derivative of those functions, which are independent of X in linear specifications. Thus, the exponential technology diffusion may overestimate the catch-up or absorptive capacity effect of X for countries or industries lying further behind the technological frontier. Note that for the frontier country, this effect is null.

[28] The functional form for the logistic diffusion process is given by:
$\Delta \ln A_i = g(X_i) + c(X_i)\left[1 - \left(A_i/A_m\right)\right] \equiv g(X_i) + c(X_i)\left(A_i/A_m\right)\left[\left(A_m/A_i\right) - 1\right]$, where $MPX = g'(X_i) + c'(X_i)\left(A_i/A_m\right)\left[\left(A_m/A_i\right) - 1\right]$. Thus, the difference of the dynamics under the logistic model of technology diffusion and the confined exponential one is due to the presence of the extra term $\left(A_i/A_m\right)$. This term acts to dampen the rate of diffusion as the distance to the leader increases, reflecting perhaps the difficulty of adopting distant or more advanced technologies.

[29] For instance, related to Griffith *et al.* (2004), this sensitivity analysis may help determine the 'true' social rate of return to R&D, a rate that has been either underestimated in the productivity literature (which ignores the imitation role of R&D) or overestimated in papers that use the exponential model of technology diffusion (which allows for both innovative and imitative roles of R&D).

[30] These policy reforms had little obvious link to industry-level innovation performance; and since they are including industry and time effects, this approach identifies the competition effect through the differential timing of the introduction of policy changes across industries. Thus, they identify the *causal* impacts of competition on innovation and productivity growth.

two equations as a measure of PMC. Their estimation results provide a strong evidence that reforms in the form of the SMP were associated with increased PMC, as measured by a reduction in average profitability, and with a subsequent increase in innovation intensity and productivity growth. More specifically, their regression analysis reveals that both competition and innovation enhance productivity growth directly. Further, greater competition induces more innovation, and consequently also raises productivity indirectly via innovation.

Although the modeling approach undertaken in Griffith *et al.* (2006a,b) is closely in line with the conceptual framework shown in Figure 1, it nonetheless involves unappealing feature that the causality runs from variations in innovation to variations in productivity and not the reverse.

4.2 Country-specific studies

There is a large number of empirical studies investigating the relationships between competition, (fundamental) innovation and productivity level and/or growth using firm-level data within a single country. Before reviewing both some of the most widely cited papers and some more recent ones, it is worth mentioning that most of them focused on the United Kingdom (UK). As rightfully mentioned in Griffith *et al.* (2006a), the UK turned out to be a good place to study the relation between product market competition and innovation because there have been a large number of policy changes which led to (relatively) exogenous variation in the nature and magnitude of product market structures and competition. These included the large-scale privatizations of the 1980s and 1990s, reforms associated with EU integration, and the opening up of markets in numerous other ways – see Figures A1 and A2 for some evidence (these figures present regulatory indicators measuring the degree of restrictions on private governance and competition, respectively).

Nickell (1996) analyzes empirically the relationship between product market competition and productivity performance. Using panel data on 670 UK manufacturing companies over the period 1975-1986, he finds that competition, measured either by increased numbers of competitors or by lower levels of rents (Lerner index), is associated with higher rates of TFP growth. In addition, he reports that market power, as captured by market share, leads to a lower level of productivity.[31]

Nickell *et al.* (1997) investigate the role of three factors in determining a firm's productivity performance: product market competition, financial market pressure (related to high debt servicing costs and risk of bankruptcy) and shareholder control. Using data from around 580 UK manufacturing firms and looking specifically at TFP, they find that all three have an impact. Competition (as measured by lower levels of rents normalized on value-added) is found to be positively related to TFP growth, interest payments normalized on

[31] Nickell (1996) is one of the studies that echoed the potential endogeneity of competition measures. It addressed this problem by various means, such as lagging the competition variables, controlling for other factors, and treating competition indicators as endogenous by using a variant of the GMM estimation technique.

cash flow are positively related to future productivity growth, and firms with a dominant external shareholder (from the financial sector) have higher productivity growth rates. They argue these results suggest that the last two factors can act as partial substitutes for competition, implying that the presence of either might attenuate the impact of increased competition on a firm.

Using panel data from 340 UK manufacturing firms between 1972 and 1982, Blundell *et al.*(1999) examine the empirical relationship between technological innovations, market share and stock market value. They find a robust and positive effect of market share on observable headcounts of innovations and patents although increased product market competition in the industry (as measured by reduced industry concentration – i.e. the proportion of sales accounted for by the five largest domestic firms) tends to stimulate innovative activity. Furthermore, they find that the impact of innovation on market value is larger for firms with higher market shares. Then, they argue that their results are consistent with models where high market share (incumbent) firms have incentives to innovate in order to pre-empt rivals.[32]

From a much larger data set of around 143,000 UK establishments over the period 1980-1992, Disney *et al.* (2000) experiment with several indicators of competition (such as industry concentration, import penetration, market share, and rents) in productivity regressions and find that market competition significantly raises productivity levels as well as productivity growth rates.

Griffith (2001) uses panel data on UK manufacturing establishments over the period 1980-1996 to investigate the relationship between product market competition (as measured by Lerner index or mark-up) and (labour and total factor) productivity levels and growth rates. The introduction of the European Union (EU) Single Market Program (SMP) is used as an instrument for the change in product market competition. The results suggest that the increase in competition brought about by SMP led to an increase in overall levels of efficiency and growth rates. The sample of firms is then split into those with a principal-agent set up and those without. The increase in efficiency occurred in principal-agent type firms, and not in those where managerial control and ownership were more closely related. She argues these findings suggest that product market competition can play an important role in reducing agency costs and may explain some of the poor performance of European economies relative to the U.S.

Using a panel of 17 UK manufacturing industries over the period 1973-1994, Aghion *et al.* (2005) test empirically the theoretical predictions of their model. They use a Lerner index (or price-cost markup) to measure variation in competition across industries. To deal with the potential endogeneity of competition they instrument product market competition with a large number of policy reforms, including the EU Single Market Program, competition policy reforms and privatizations. Their results indicate a strong evidence of an inverted-U relationship between innovation, as measured by the citation weighted patent count, and product market competition – the peak of the inverted-U lies

[32] Nickell *et al.* (1997) and Blundell *et al.* (1999) followed similar techniques as in Nickell (1996) to address endogeneity of competition measures.

near the median of the distribution. Moreover, their empirical results lend support to two other theoretical predictions – that the average technological distance between leaders and followers (as measured by differences in TFP) increases with competition, and that the inverted-U is steeper when industries are more neck-and-neck (i.e. industries characterized by competing firms with similar technological level and unit costs).

Aghion *et al.* (2004a, 2004b) investigate empirical support, using a panel of UK manufacturing firms covering 1987-1993, for the main theoretical predictions of their model. To do that, they look at the relationship between foreign firm entry (which reflects competition intensity) and TFP growth in domestic incumbent firms, and examine how this relationship varies with a firm's (or an industry's) distance to the technological frontier. Endogeneity (relative changes in the entry rate across industries may be indirectly caused by shocks to productivity or patenting) is controlled for using policy[33] and foreign technology variables as excluded instruments that determine entry but have no direct effect on the growth in TFP or patenting. They find that the impact of foreign firm entry on TFP growth in domestic incumbent firms is positive, statistically significant (when entry is instrumented the coefficient gets larger, indicating a negative bias) and economically significant. Increasing the entry rate from the mean by one standard deviation (from 0.44% to 3.8%) would result in a rise in the average growth rate of TFP about 1.3 percentage points. Furthermore, when they interact entry with an incumbent's distance to the technology frontier, the results suggest that the effect of entry on TFP growth is larger when an industry is closer to the technological frontier. In industries that lag far behind the frontier, higher entry or higher competition on their own tend to discourage incumbent firms from innovating, since even by doing so, they would not progress sufficiently to compete successfully with new firms.

Greenhalgh and Rogers (2006) analyze empirically the market valuation of innovative activities by UK production firms using a panel data set (1989-2002) on their R&D and intellectual property (IP) activities. Grouping firms by sectors, they first find that the valuation of R&D varies substantially across these sectors. To explore these variations, they link competitive conditions with the market valuation of innovation. Using profit persistence as a measure of competitive pressure, they find that the sectors that are the most competitive have the lowest market valuation of R&D. Furthermore, within the most competitive sector, firms with larger market shares (an inverse indicator of competitive pressure) also have higher R&D valuations. They conclude that this evidence supports Schumpeter by finding higher returns to innovation in less than fully competitive markets and contradicts Arrow who argued that, with the existence of IP rights, competitive market structure provides higher incentives to innovate.

Gustavsson and Poldahl (2006) examine whether Aghion *et al.* (2005) model's predictions are supported by firm-level data and how robust they are across the use of different estimators and measures of competition. In particular, they examine if there is an inverted U-shaped relation between competition and R&D. To achieve this, they use

[33] The instruments used are: investigations and decisions by the Monopoly and Merger Commission, privatization cases of large publicly owned companies and indicators for 3-digit industries expected to be highly affected by the EU Single Market Program.

Swedish firm-level data covering the Swedish manufacturing industry spanning the period 1990-2000. Their results show that the inverted U-shaped relation is supported by the Herfindahl index but not by the price-cost margin, where the latter is treated as an endogenous variable. Using the Herfindahl index, results suggest that breaking up monopolies increases R&D, whereas further increases in competition most likely lead to reduced R&D. Comparing different estimators, they find that time series-based estimators typically result in less clear-cut results, probably driven by a lack of time series variation in measures of competition. Also, as suggested by Aghion *et al.* (2005), their results (using the Herfindahl index) support a complementarity between the degree of neck-and neckness and competition – i.e. the positive escape competition effect boosts R&D most when firms compete neck-and-neck (i.e. with similar technological level and unit costs).

Following basically the empirical strategy by Nickell (1996), Okada (2005) examines the determinants of productivity in Japanese manufacturing industries, looking particularly at the impact of product market competition on productivity. Using panel data on around 10,000 firms in Japanese manufacturing for the years 1994-2000, the author shows that competition, as measured by lower level of industrial price-cost margin, enhances productivity growth, controlling for a broad range of industrial and firm-specific characteristics. Moreover, his results indicate that market power, as measured by either individual firm's price-cost margin or market share, has a negative impact on productivity level of R&D performing firms.

Mohnen, P. and Th., ten Raa (2003) investigate the effect of competition (in factor markets) on TFP growth. As a negative measure of competition they use rent (which is defined as the excess factor rewards over and above their perfectly competitive values – marginal productivities). Using input-output analysis to calculate rent for the Canadian sectors over a thirty-year period and to decompose it in its capital and labour components, they find that rent has no significant influence on productivity. However, they report that the components influence productivity in opposite directions, i.e. capital rent has a positive role and labour rent a negative one. They argue that the neoclassical economists (who advocate that competition promotes efficiency) and Schumpeter seem both right, but the mechanisms differ: the use of rent as a source of funding for R&D applies to capital and the argument that rent yields slack pertains to labour.

Tang and Wang (2005) estimate the impact of product market competition (among others) on the productivity level performance of Canadian manufacturing firms. Using firms' perceptions of their competitive environment from the Statistics Canada 1999 Survey of Innovation to measure product market competition, they find that product market competition has a positive impact on the performance of medium-sized and large-sized firms.

Finally, Baggs, J. and J.E. de Bettignies (2006) exploit Statistics Canada's Workplace and Employee Survey (WES) rich dataset to analyze the effects of product market competition on firms' strategies, the types of contracts and incentives they offer to their employees, and on individual employee effort. Consistent with their theoretical model predictions, they find the following empirical results. First, the importance firms place on quality improvements and cost reductions, the presence of contractual incentives, and the

number of unpaid overtime hours employees work, all *increase* with product market competition. Second, the effects of competition on these three variables are generally *larger* for firms with *more* employees and/or more hierarchical structures, where agency costs are more likely to be present. Lastly, they observe these effects *sequentially*, i.e. competition increases the importance firms place on quality improvements, which is, in turn, positively associated with greater reliance on incentive contracts, while incentive-based contracts lead to higher effort exertion.

To sum up, it appears that apart from a handful of studies, the empirical literature on the whole (both cross-country and country-specific studies) points to a positive effect of competition on innovations (fundamental and applied) and productivity.

5 Conclusions

It is widely acknowledged that over long periods of time, productivity is the single most important determinant of a nation's living standard or its level of real income. Consequently, many policy makers and academics are particularly concerned about Canada's lagging productivity level and/or growth relative to several OECD countries, and in particular to the U.S. Among the factors that have been put forward to explain Canada's weak productivity performance with respect to the U.S., there are: lower investment in fundamental innovation (as measured, e.g., by R&D intensity), lower investment in applied innovation or the adoption and diffusion of new technologies (as measured, e.g., by ICT investment share), and the lack of competitive pressures (e.g., in product markets).

However, according to conventional wisdom, greater competition increases the pressure for firms to innovate and adopt and use new productivity-enhancing technologies such as ICT. Thus, in addition to its direct impact on productivity, a high level of competition may enhance productivity indirectly through its effects on innovation and investments in technology adoption (i.e. fundamental and applied innovation, respectively). To ascertain this widespread view, this paper reviews some (recent and/or influential) theoretical literature and empirical evidence on the impacts of competition on innovations (fundamental and applied) and productivity. In addition, it neatly compares the advantages and disadvantages of the most widely used measures of competition in empirical studies.

Although there is no obvious and accurate way to measure competition, the price-cost margin (or mark-up) and indicators of regulatory reforms seem preferable (despite some shortcomings) for cross-country and -industry studies. Besides, the literature review reveals that the effects of competition, particularly on innovations, are quite controversial at a theoretical level. However, apart from a handful of studies, the empirical literature on the whole (both cross-country and country-specific studies) points to a positive effect of competition on innovations and productivity.

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Figure A1: Regulation indicator: public ownership, 1975-2003

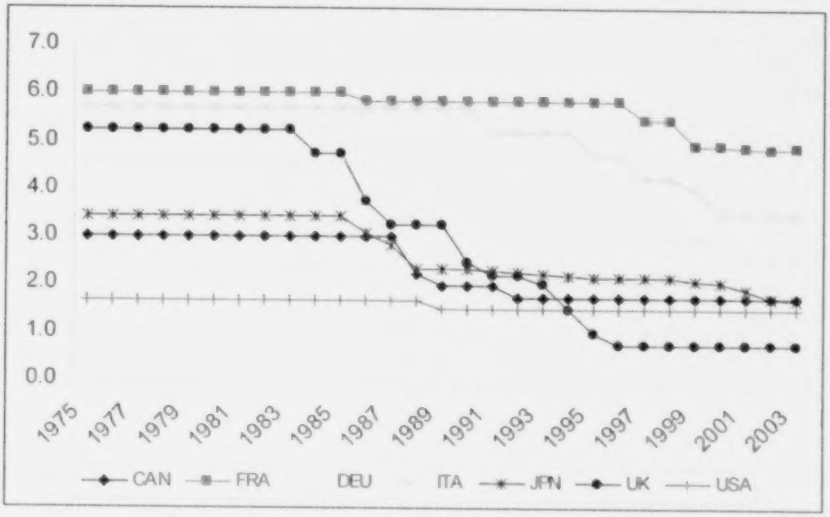
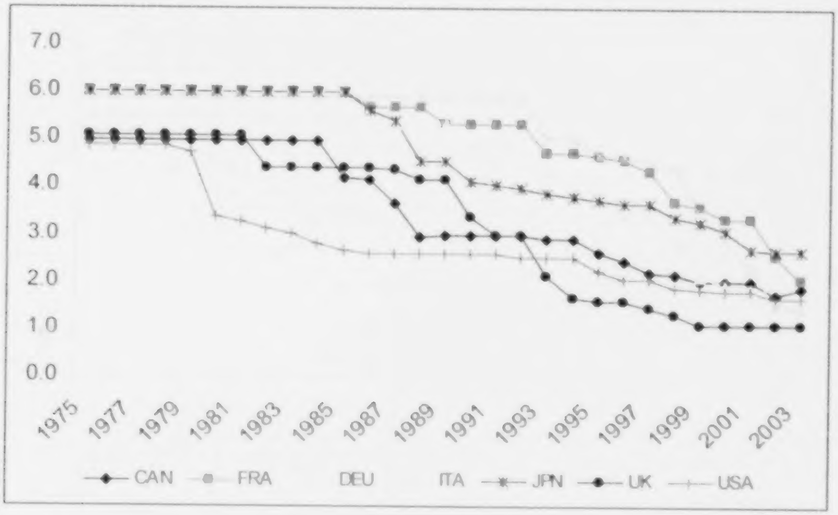


Figure A2: Regulation indicator: the barriers to entry, 1975-2003
(comprising legal restrictions and vertical integration)



Sources (**Fig. A1 and A2**): Our calculations based on OECD database

Notes (**Fig. A1 and A2**): The regulatory indicator ranges from 0 (least restrictive) to 6 (most restrictive) and represents average for seven non-manufacturing industries: transport (airlines, road freight and railways), communication (telecommunications and postal services) and utilities (electricity and gas). Countries: Canada (CAN), France (FRA), Germany (DEU), Italy (ITA), Japan (JPN), United Kingdom (UK), and United States (USA).